

Aligned with your needs.

# Human Interface Evaluation Methods for Submarine Combat Systems

Bonnie Hautamaki  
Ron Small

7 June 2006



**ALION**  
SCIENCE AND TECHNOLOGY



## Introduction – Phase I SBIR *Human Interface Evaluation Methods for Submarine Combat Systems*

- NAVSEA PMS-425 - Sponsor
  - Mr. Nickolas Guertin
- Naval Undersea Warfare Center (NUWC) – TPOCs in Newport, RI
  - Dr. Joseph Gabriel
  - Ms. Megan Gibson
  - Dr. Susan Kirschenbaum
  - Chief Jerrett S. Boehning, FTC (SS/DV)



## So what's the problem?

### **Combat System (CS) operator's job**

- Goal: maintain an accurate tactical picture
  - Surface, sub-surface
- Receive contact data from sonar party
- Perform target motion analysis (TMA)
- Determine solution for each contact of interest
- Update solutions



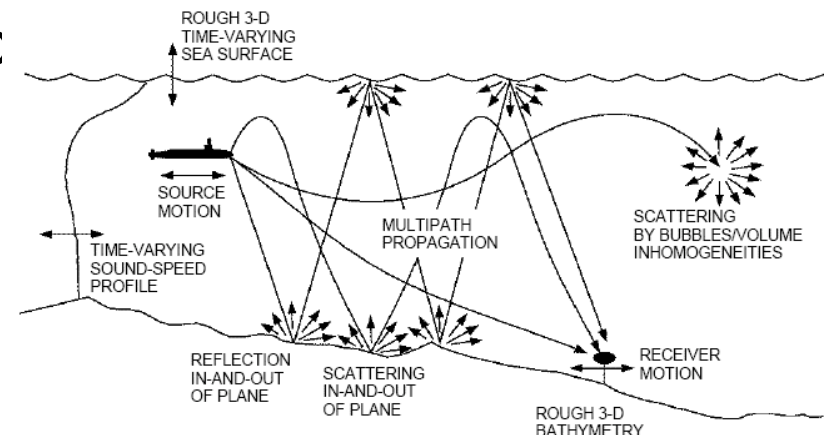
# Challenges for the CS operator

## Data-related challenges

- Massive quantity of sensor data
- Inherent uncertainty in sensor data
- Requires quick, accurate sorting & prioritization
- Contacts could be hostile

## Environmental challenges

- Severe consequences for errc
- Work as quickly as possible
- Underwater hazards
- Threat situation
- Underwater acoustics





## Some overall challenges...

1. The inherent uncertainty of the operating environment provides significant opportunity for error.
2. More information is not necessarily better.
  - A multitude of alerts for isolated incidents can cause more harm than good.
  - Collectively, a set of alerts can carry more weight than they do individually.
3. So how to manage alerts?
  - Want operator to be well-informed
  - But don't overload operator with data



## Example: Alert Manager window

### *Tactical Control /Weapons Control interface*

- Operator must look directly at window to see alerts
- Alerts noted individually rather than grouped and connected
- All alerts are presented in a similar manner (text on screen)



## The design challenge

- To produce a system that helps the CS operators without increasing the system complexity.
- Identify a potential aid for users that could:
  - Assimilate information for the user (similar to “grouping”)
  - Prioritize alerts
  - Provide alerts at the right time, in a mode suitable for the conditions and the severity
  - Inform operator of alert, even if he is not looking at screen



## MA&D's approach

1. Choose metrics
  - For evaluating operator performance
2. Model a baseline system
  - Focused on the human operators & their tasks
3. Select a system enhancement
4. Change model to reflect system enhancements
5. Compare operator performance
  - Baseline model vs. enhanced system model



## Metrics

1. Metrics allow for comparison of model's operator performance to system requirements.
2. Not necessary to show improvement in every category – but want clear indication of overall improvement.



## Developed a scenario

Key elements: ASW, Coming to PD, Transiting a strait, ASUW



6/16/06

Not to Scale

Legend: O = other ships or boats



# Scenario timeline (excerpt)

| Elapsed time from T <sub>0</sub> (H+MM)         | 0+00                  | 1+05                     | 1+12                            | 1+42                              |
|---|-----------------------|--------------------------|---------------------------------|-----------------------------------|
|   | T <sub>0</sub>        | T <sub>1</sub>           | T <sub>2</sub>                  | T <sub>3</sub>                    |
| Duration  | 0+00                  | 1+05                     | 0+07                            | 0+30                              |
| Positions                                       |                       |                          |                                 |                                   |
| Ownship location                                | ~27 nm < Strait       | ~26 nm < Strait          | ~23 nm < Strait                 | ~22 nm < Strait                   |
| M-5 location                                    | ~25.5 nm < Strait     | ~24 nm < Strait          | ~21 nm < Strait                 | ~20 nm < Strait                   |
| Goals   | Close trail of M-5    | Prepare for PD           | Navigation Fix                  | Return to depth                   |
|   | Remain undetected!    | Open range to M-5 for PD | Communicate                     | Resume track                      |
| Sub-Goals                                       | Distance to M-5 track | Sonar search             | Turn toward M-5                 | Update SVP in dive                |
|   | Depth differential    | Clear baffles            | Visual search                   | Update current set & drift        |
|   | Match speed in LOS    | Visual search            | Prepare to dive                 | Set course, speed, depth          |
|   | Range = 1-2 nm        | SVP updates              |                                 |                                   |
| Ownship States                                  |                       |                          |                                 |                                   |
| True course (degrees)                           | ~270                  | ~360                     | ~360 - 225                      | ~225 - 270                        |
| Speed (knots)                                   | ~9                    | ~7-15                    | ~4-6 at PD                      | ~14-15 knots                      |
| Depth (feet)                                    | ~250                  | ascent 5° - 6°           | PD (sea state = 3)              | ascent to 200 ft down, initially) |
| Range to M-5                                    | ~1-2 nm               | ~4-5 nm                  | ~4-5 nm                         | ~3-4 nm, closing                  |
| Distance to M-5 track                           | right, 1 kyds         | na                       | na                              | na                                |
| Speed in LOS (knots)                            | none                  | na                       | na                              | na                                |
| Depth difference between ownship and M-5 (feet) | ~50-100               | na                       | na                              | na                                |
| Errors, Hazards                                 | Too close             | Fail to detect contacts  | Get detected!                   | Get detected!                     |
|   | Too far               | Bad choice of turn away  | Lose M-5 while at PD            | Lose M-5                          |
|   |                       | Lose M-5                 | Too fast at PD (wake & feather) |                                   |
|   |                       |                          | Too long at PD                  |                                   |



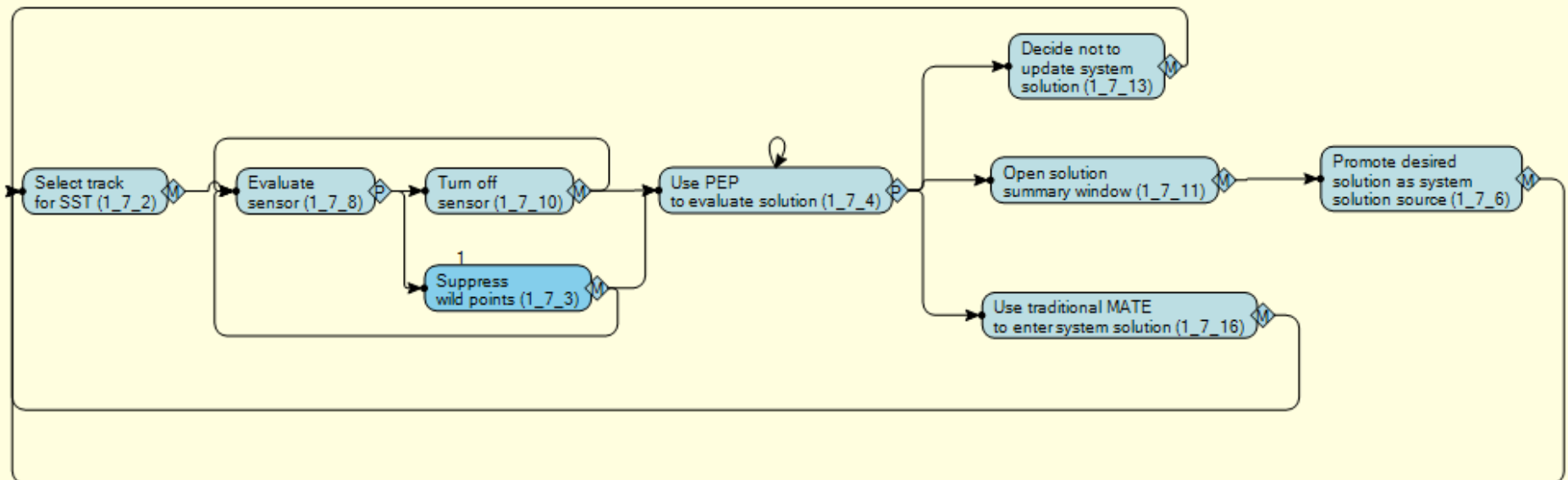
## Mission metrics

| <b>Mission Metric</b>                | <b>How measured</b>  |
|--------------------------------------|--|
| Closest point of approach of hazards | Miss distances in 3D to other ships or obstacles                               |
| Area of uncertainty (AOU) overlap    | Time and amount of overlapping AOUs with hazards                               |
| Abrupt maneuvering                   | Number and suddenness of maneuvers to avoid hazards                            |
| Proper track position                | 3D distance from desired track (especially in relation to contact of interest) |



# Developed a task-network model

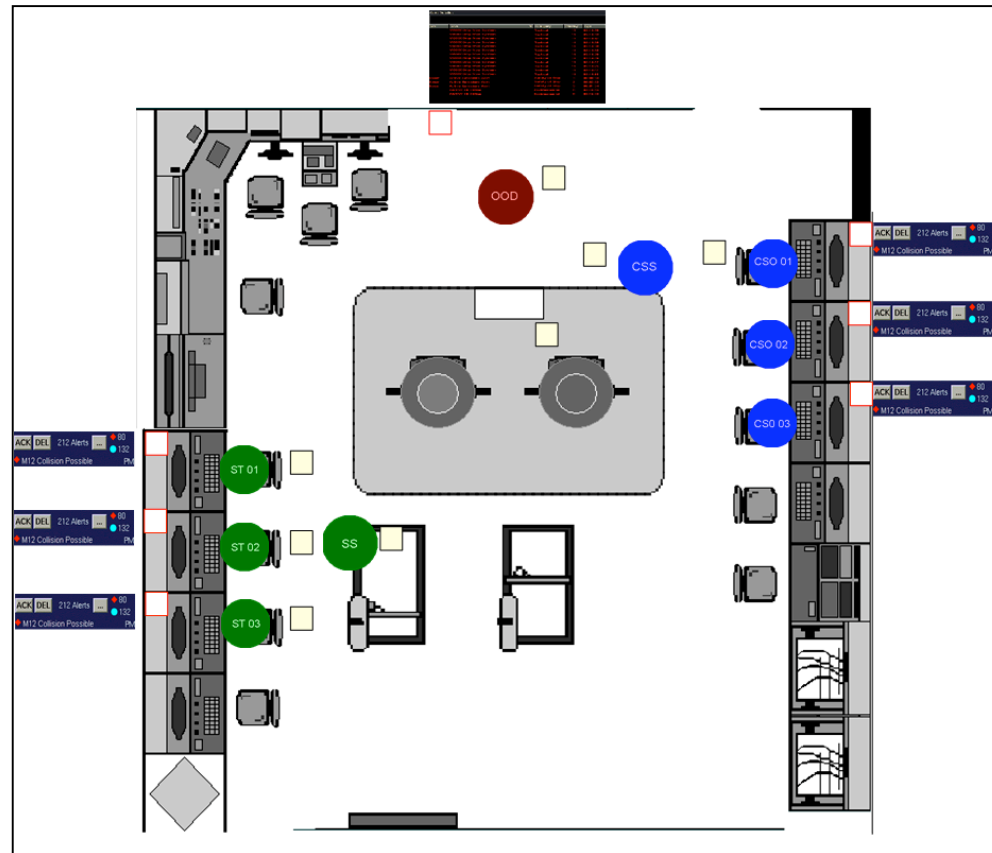
CSO01 Current Focus  
CSO01.Classification: Deep Draft Tanker  
CSO01.Designation: S0  
CSO01.Identification: Civilian



- Focus of model: Combat System operator
- Also modeled sonar party



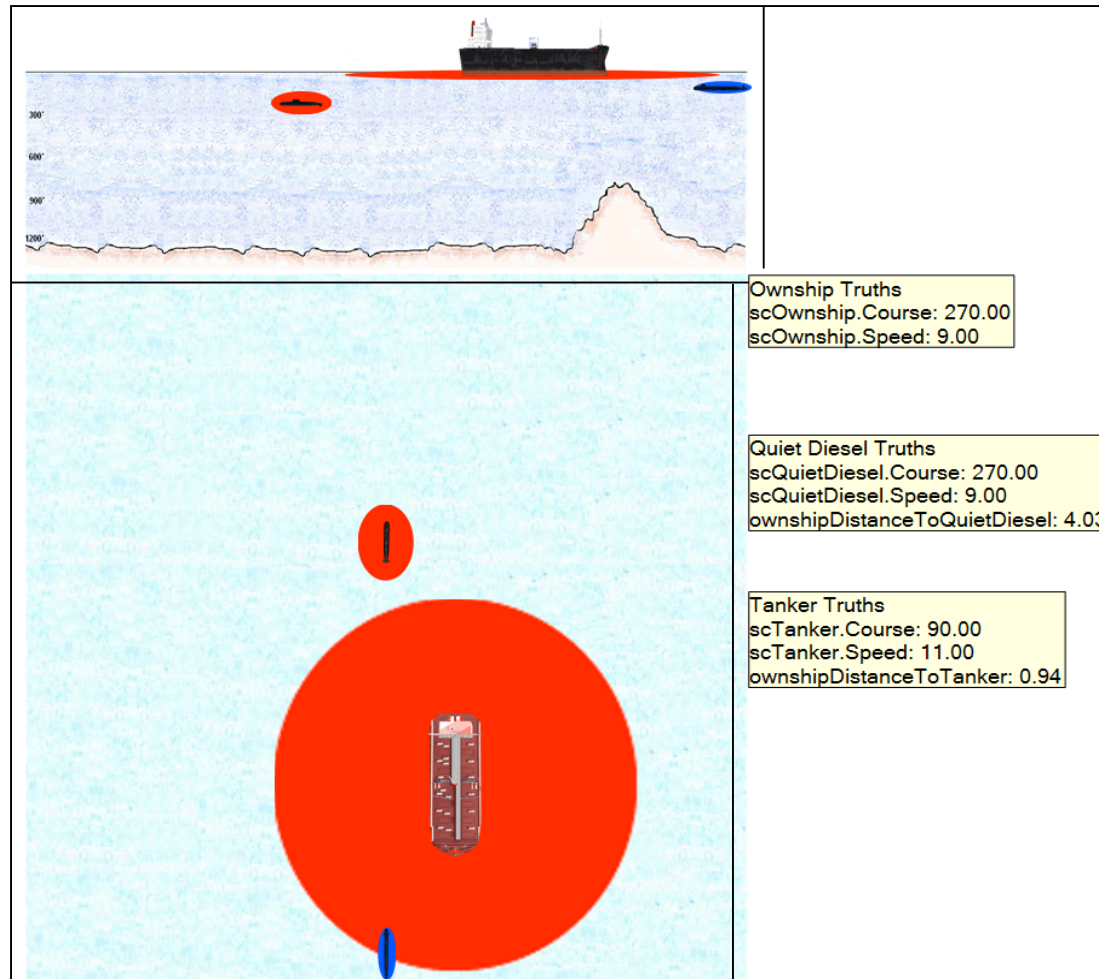
## Added control room animation



- For better visualization of task-network model behaviors
- Information flow between persons in control room
- Indication of alerts



## Geographical area of uncertainty



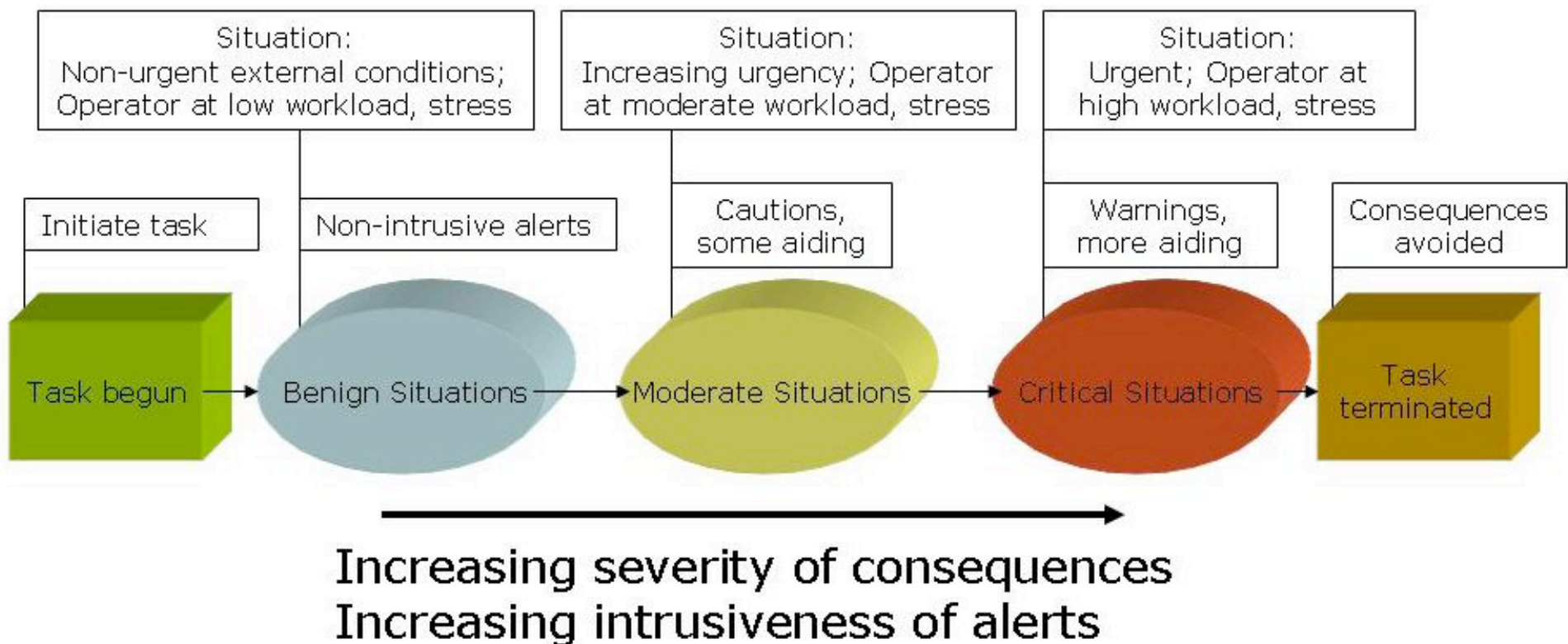
- CS operator has not updated manual solution
- AOU for deep-draft tanker has grown; overlaps ownship



# Error Monitor → HMIAS

## *Hazard Monitor & Intelligent Alerting System*

### Generic CCS Operator Error/Hazard Network





## Increasing levels of alerts

| <b>Alert</b>  | Initial | 2 <sup>nd</sup>   | 3 <sup>rd</sup>                   | 4 <sup>th</sup>   |
|---------------|---------|-------------------|-----------------------------------|---|
| <b>Format</b> | Text    | Text,<br>flashing | Text,<br>flashing,<br>audio alarm | Text, flashing,<br>audio alarm,<br>plus audible<br>instructions |

Increasing levels of intrusiveness





## Results: Model Comparison

*Goals: Avoid collision, Track quiet diesel submarine*

### Metrics:

1. Closest distance, ownship to deep-draft tanker at time of evasive maneuver
2. Distance from ownship to quiet diesel at time tracking is resumed
3. Angle off tracking course once tracking is resumed

| Mission Performance Metric  | Without HMIAS (Baseline)     | With HMIAS                   | Change*                         |
|---|------------------------------|------------------------------|---------------------------------|
| CPA to deep-draft tanker hazard                                       | Approx. 0.5 nm (1000 yards)  | Approx. 1.0 nm (2000 yards)  | 2x distance to hazard           |
| Distance to quiet diesel submarine after avoiding tanker (goal = 4nm) | 4.71 nm (approx. 9540 yards) | 4.14 nm (approx. 8385 yards) | Closer to goal of 4 nm          |
| Angle off desired track after avoiding tanker                         | 90 degrees                   | 30 degrees                   | Smaller angle off desired track |

\* Notional results from enhanced system



## Conclusion

1. Groundwork: understanding & improving decisions made at the command level
2. Findings from operator task-network model: potential to apply toward system, employment and training improvements
3. Developed tools, metrics, methodology - may apply to complex control systems in other domains (military & industry)
4. HMIAS:
  - Benefit from increasing intrusiveness → prevent errors & consequences
  - Increase situation awareness & disseminate critical information for improving operator interfaces.



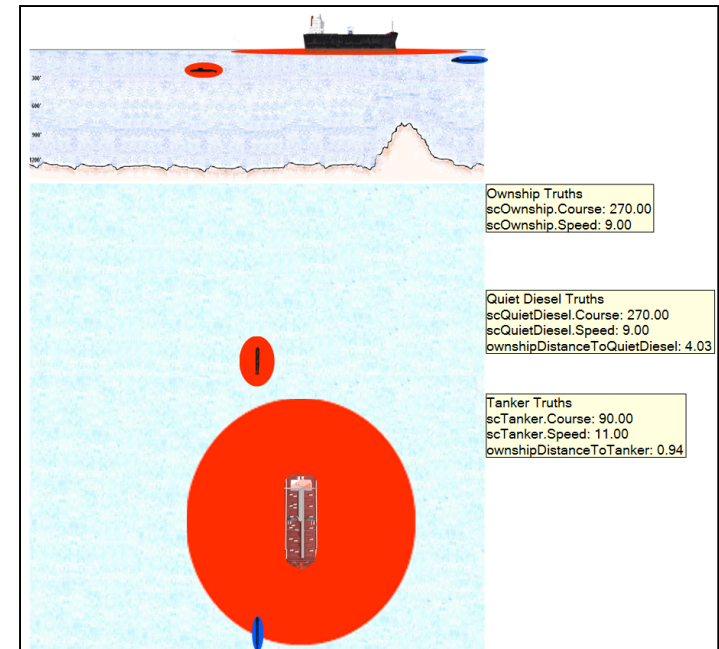
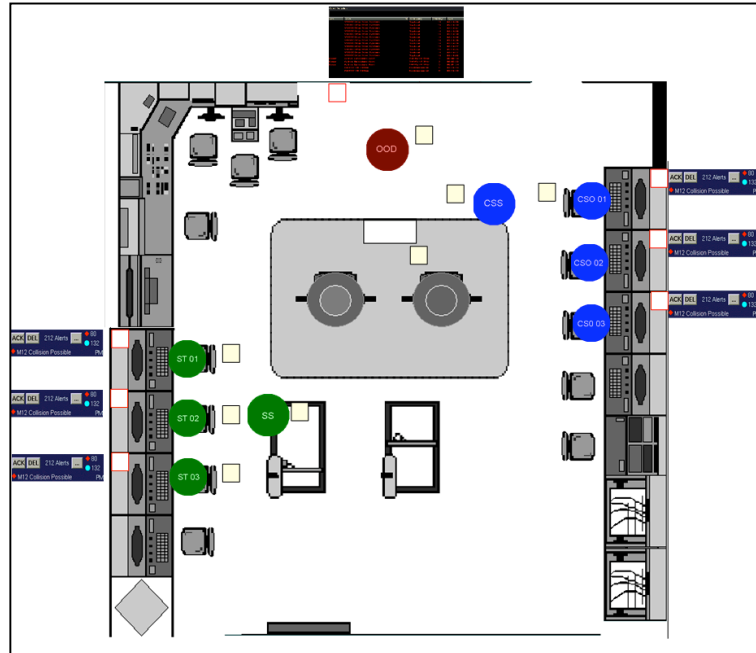
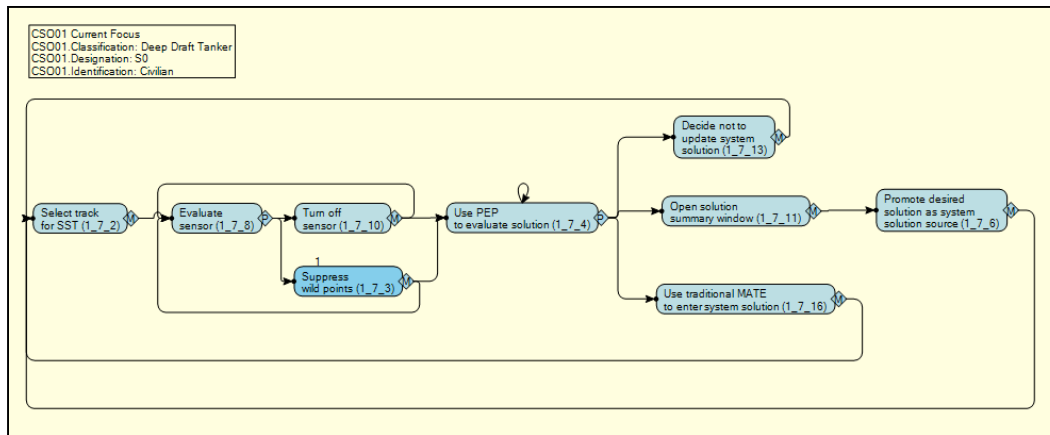
## What's next?

Submitted proposal to continue research:

1. Further develop the baseline task-network model
2. Develop HMIAS prototype
3. Identify display improvements for CCS interfaces
4. Pursue development of innovative displays related to uncertainty



# Model Demo





# Questions?



# Thank you!

Bonnie Hautamaki

Ron Small

Alion Science and Technology  
MA&D Operation

4949 Pearl East Circle, Suite 300

Boulder, CO 80301

303.442.6947

[www.maad.com](http://www.maad.com), [www.alionscience.com](http://www.alionscience.com)

[bhautamaki@alionscience.com](mailto:bhautamaki@alionscience.com)

[rsmall@alionscience.com](mailto:rsmall@alionscience.com)

© 2006 Alion Science and Technology